ELECTRIC AND NONELECTRIC MOTH TRAPS BAITED WITH THE SYNTHETIC SEX PHEROMONE OF THE TOBACCO BUDWORM

ARS-S-173

February 1978

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

ACKNOWLEDGMENTS

The authors wish to thank Luis B. Ortiz, director, Isabela Substation, University of Puerto Rico Agricultural Experiment Station, and his staff for the excellent cooperation and courtesies extended them during the conduct of trial 3 in Puerto Rico.

The assistance of Robin Roark and Leslie Campbell, student workers at Texas Agricultural Experiment Station, in constructing and servicing traps is also gratefully acknowledged.

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
in cooperation with
Texas Agricultural Experiment Station

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ELECTRIC AND NONELECTRIC MOTH TRAPS BAITED WITH THE SYNTHETIC SEX PHEROMONE OF THE TOBACCO BUDWORM

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ABSTRACT

A modified commercial grid trap and two miniature versions of a standard grid trap were compared in two trials with a standard grid trap for catching male tobacco budworm moths, *Heliothis virescens* (F.). In a third trial, six nonelectric trap designs were evaluated for trapping male tobacco budworm moths and cabbage looper moths, *Trichoplusia ni* (Hübner), using the commercial grid trap as a standard of comparison. In each of two final trials, five nonelectric trap configurations were compared with the standard grid trap for trapping male tobacco budworm moths. The traps in all trials were baited with virelure, the synthetic pheromone of the tobacco budworm. Results of the first two trials showed that the modified commercial trap was slightly better in performance than the standard trap, and both of these traps outperformed the miniature traps. In the third trial, the commercial grid trap was the only trap that consistently caught moths, catching 93% of all tobacco budworm moths and 57% of all cabbage looper moths caught. In the final trials, the standard grid trap outperformed all other traps. However, one trap, consisting of a wire mesh cone with no bottom, caught 52% of the total number of moths caught by the standard trap, a better performance than that of any of the other nonelectric traps. This trap is portable, lightweight, and inexpensive and appears to be a practical design that opens up possibilities for widespread use of nonelectric insect traps. **KEYWORDS:** ***Heliothis virescens*** **(F.), insect-trap design, insect traps (electric), insect traps (nonelectric), pheromones (synthetic),** ***Trichoplusia ni*** **(Hübner), virelure.**

INTRODUCTION

Black-light electric insect traps are presently used to provide daily data on population levels of the bollworm, *Heliothis zea* (Boddie), and the tobacco budworm, *Heliothis virescens* (F.) (*3, 4*)[4]. These data, with associated environmental and crop phenology data, are used to initiate computer-oriented population models that output timing predictions for future population peaks.

Virelure, the synthetic sex pheromone of the female tobacco budworm, was synthesized in 1975 (*8*) and became commercially available in 1976. This pheromone was proven an effective

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[4] Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

attractant for male tobacco budworm moths in field trials conducted by Agricultural Research Service's Cotton Pest Control Equipment and Methods Research Unit at College Station, Tex., during 1975 and 1976 when an electric-grid trap was used (*2*). Since analysis of grid-trap catch data indicated that monitoring of populations by using traps baited with the synthetic pheromone might provide extremely useful model input data for early-season predictions, efforts were undertaken to design a pheromone trap especially for tobacco budworm adults. Initial efforts were concerned with developing a small, inexpensive, electric grid with the potential for replacing the conventional grid survey trap described by Wolf et al. (*10*), Mitchell et al. (*7*), and Stanley et al. (*8*).

The developmental design and test procedures presented in this report evolved through two major phases: (1) evaluation of electric trap designs and (2) comparison of electric and nonelectric trap designs.

EQUIPMENT, METHODS, AND RESULTS

Evaluation of Electric Trap Designs

Trial 1

Two new trap configurations were evaluated from August 2 to September 8, 1976, in the Brazos River Valley area, Burleson County, Tex., for trapping male tobacco budworm moths. The standard grid trap (SG) was compared with a modified commercial grid trap (CG)[5] and a miniature version of the standard grid trap (6MG) (figs. 1–3).

The grid for the modified commercial grid trap, as shown in figure 2, was adapted for mounting above a funnel and collection container assembly. The trap was further modified by removing the 15-W black-light attractant lamp and substituting a holder for the pheromone attractant and by substituting a 4-mA, 4,000-V, a.c., current-limiting transformer for the normally used 9-mA, 4000-V transformer.

The steel grid wires, three thirty-seconds of an inch (2.4 mm) in diameter, are chrome plated and are spaced to provide a gap opening of three-eighths of an inch (9.5 mm) between

FIGURE 1.—Trap SG, the standard grid trap.

grid wires. The cylindrical grid is 8 inches (20.3 cm) in diameter and 18 inches (45.7 cm) in height. The transformer housing to which it is attached is 10½ inches (26.7 cm) in diameter and 7 inches (17.8 cm) in height. The grid is mounted above a funnel having a top diameter of 20 inches (58.9 cm), height of 17 inches (43.2 cm), and base opening of 2 inches (5.1 cm) at point of attachment to the collection container. The collection container is cylindrical, with a 12-inch (30.5-cm) diameter and 10-inch (25.4-cm) height. Small drill holes in the base of the container allow for moisture drainage. The collection container contains resin strips fortified with dichlorvos insecticide[6] for killing moths that are knocked down but not killed by the grid.

The cylindrical grid of the miniature trap (fig. 3) is 3 inches (7.6 cm) in diameter and 6 inches (15.2 cm) in height. The grid wires are made of stainless-steel rods, one-eighth of an

[5] Mr. ZAPP, model S, manufactured by Gardner Manufacturing Co., Horicon, Wis. 53032.

[6] Starbar Insect Strip, distributed by Starbar, a division of Thuron Industries, Dallas, Tex. 75234.

FIGURE 2.—Trap CG, a modified commercial grid trap.

FIGURE 3.—Trap 6MG, a miniature version of standard grid trap SG.

inch (3.2 mm) in diameter, spaced one-half of an inch (12.7 mm) apart. The top ends of the rods fit into and extend through a Teflon disk 3 inches (7.6 cm) in diameter and 1 inch (2.5 cm) in thickness. Alternate grid wires are made electrically common by two circular rings at the base of the grid assembly. Electrical connections are made to projecting grid wires at the top of the Teflon disk. High voltage to energize the grid is supplied by a 4,000-V, a.c., 4 mA, current-limiting transformer mounted within the upper housing. The grid is mounted above a funnel and collection container assembly identical to those used for the other two traps.

The traps were baited with virelure (*9*) contained in ½- by 1-inch (1.3- by 2.5-cm) laminated plastic.[7] Each bait contained 20 mg of active material and was suspended within and near the center point of the cylindrical grid. Fresh baits were installed at weekly intervals, and traps were serviced daily to collect and count moth catches and to interchange trap positions.

Results of this three-trap comparison are presented in table 1. Modified commercial trap CG was slightly better than standard trap SG, and both outperformed miniature trap 6MG. The difference in catches between traps CG and SG could have been due to the condition of the insulators on the SG traps, which had been in field use for the previous 2 years. Trap CG was new and the insulators still maintained high impedance between grids, a requirement for maximum sparking and knockdown ability. The performance of trap 6MG was disappointing, since we had visualized possibilities of a small portable trap adapted to operate on four to eight dry-cell batteries or on a similar small power pack.

An attempt was subsequently made to determine reasons for the poor performance of the small grid by observing the behavior of moths as they approached the trap. Limited observations made in a large screen cage containing pigeonpeas and a dense population of laboratory-reared *H. virescens* indicated that per-

[7] Formulated by Herculite Protective Fabrics Corp., New York, N.Y. 10010.

TABLE 1.—*Catches of male tobacco budworm moths by three electric grid traps, trial 1*

Date	Trap[1]						Replicate[2]
	SG		CG		6MG		
	Location	Catch	Location	Catch	Location	Catch	
Aug. 2	3	7	2	6	1	2	1
3	3	21	1	15	2	0	2
4	2	34	1	14	3	0	1
5	1	16	2	30	3	2	2
9	1	18	3	16	2	3	1
10	2	6	3	19	1	0	2
11	1	9	3	10	2	0	3
12	2	14	1	32	3	2	3
13	3	12	1	42	2	3	4
14	3	42	2	67	1	4	3
15	1	26	2	21	3	0	4
16	2	21	3	16	1	8	4
17	1	51	2	15	3	7	5
18	2	35	1	61	3	2	6
19	2	8	3	14	1	1	5
20	3	5	2	17	1	5	6
21	1	24	3	7	2	3	6
22	3	4	1	49	2	4	5
23	3	32	1	46	2	2	7
24	3	31	2	15	1	13	8
30	2	9	1	35	3	3	8
31	1	56	2	11	3	9	7
Sept. 1	1	32	3	27	2	3	8
2	2	19	3	11	1	16	7
3	3	40	2	49	1	8	9
4	3	30	1	79	2	27	10
5	2	39	1	50	3	16	9
6	1	43	2	75	3	4	10
7	1	18	3	63	2	8	9
8	2	21	3	59	1	7	10
Total	...	723	...	971	...	162	...
Mean[3]	...	24.1b	...	32.4a	...	5.4c	...

[1] SG, standard grid trap. CG, modified commercial grid trap. 6MG, miniature version of standard grid trap.

[2] Numbers show groupings by which data were analyzed, i.e., all 1's were of the same replicate, all 2's were of the same replicate, etc.

[3] Means not having a letter in common are significantly different at the 1% level by Duncan's multiple-range test.

formance might be improved by reducing the diameter of the transformer housing above the grid and by increasing the length of the grid. These conclusions were based on observations which showed that the moths avoided the transformer housing above the grid by flying downward as they approached the housing. This often caused them to completely miss the short 6-inch (15.2-cm) grid mounted below the housing.

Trial 2

Standard trap SG, commercial trap CG, and a miniature trap (12MG) were tested from September 13 to October 26, 1976, for trapping male tobacco budworm moths. Trap 12MG is identical to trap 6MG except that the grid length was increased from 6 inches (15.2 cm) to 12 inches (30.5 cm), and the diameter of the transformer housing was reduced from 10½

inches (26.7 cm) to 6 inches (15.2 cm). The traps were baited and serviced as in trial 1.

As previously indicated, design criteria for trap 12MG were established from the results of trial 1 and from observations of moth behavior. However, these design changes did not improve performance and, in fact, reduced it slightly, from 8.7% of total catch in trial 1 to 7% of total catch in trial 2 (table 2). The performances of traps SG and CG were not significantly different in this trial, although the mean catch of trap CG was slightly higher than that of trap SG.

Comparison of Electric and Nonelectric Trap Designs

Trial 3

In order to expedite developmental work, the first of a series of comparison trials for electric and nonelectric traps was conducted in 1977 at the Agricultural Experiment Station at Isabela, P.R., during the period February 12–20. This site was selected because of extensive plantings of pigeonpeas (*Cajanus cajan* Millsp.), a favorite host plant of the tobacco budworm. The performances of six nonelectric trap designs were evaluated for trapping male tobacco budworm moths and cabbage looper moths, *Trichoplusia ni* (Hübner), using commercial trap CG (fig. 2) as a standard of comparison.

Design concepts from a "saucer" trap (*6*) and a "wind vane" trap (unpublished data) were incorporated into the basic nonelectric trap (TP) design (fig. 4). The base of trap TP is a flat surface, and the entrance opening height is 2 inches (5.1 cm), as in the saucer trap. The top of the galvanized sheet-metal cone interfaces with a collection jar that contains a screen cone having a small aperture exit for preventing moth escape. As with the wind-oriented live trap, night skylight is visible to the moth as it enters the trap, approaches the pheromone source, and seeks to escape toward the sky, or in this case, into the collection jar. The 360° opening of trap TP eliminates the need for the wind-vane orientation, greatly simplifying construction and reducing trap size.

The cone base is 20 inches (50.8 cm) in diameter and is truncated at a height of 15¾ inches (40 cm), leaving a 4¼-inch (10.8-cm) opening for attachment of a wide-mouth jar

TABLE 2.—*Catches of male tobacco budworm moths by three electric grid traps, trial 2*[1]

Date	Trap[2]		
	SG	CG	12MG
Sept. 13	21	23	1
14	23	47	4
15	20	36	2
16	26	58	3
20	32	41	1
21	52	63	12
22	3	11	1
23	8	21	0
24	15	43	0
25	43	65	1
27	3	2	1
28	74	87	13
29	74	74	13
30	66	28	7
Oct. 1	21	48	10
2	2	30	3
4	207	128	37
5	11	20	1
6	34	18	7
7	3	1	0
8	0	0	0
9	27	19	2
10	6	13	3
11	10	16	1
12	7	11	1
13	3	4	2
14	7	18	4
15	15	4	0
18	16	30	0
19	0	0	0
20	0	0	0
21	0	0	0
22	23	0	6
23	4	4	3
24	3	6	1
25	3	6	0
26	2	0	0
Total	864	975	140
Mean[3]	23.4a	26.4a	3.8b

[1] Catches for each date used as replicate in analysis of variance.

[2] SG, standard grid trap. CG, modified commercial grid trap. 12MG, trap identical to trap 6MG except for longer grid and reduced diameter of transformer housing.

[3] Means not having a letter in common are significantly different at the 1% level by Duncan's multiple-range test.

FIGURE 4.—Trap TP, the basic nonelectric trap.

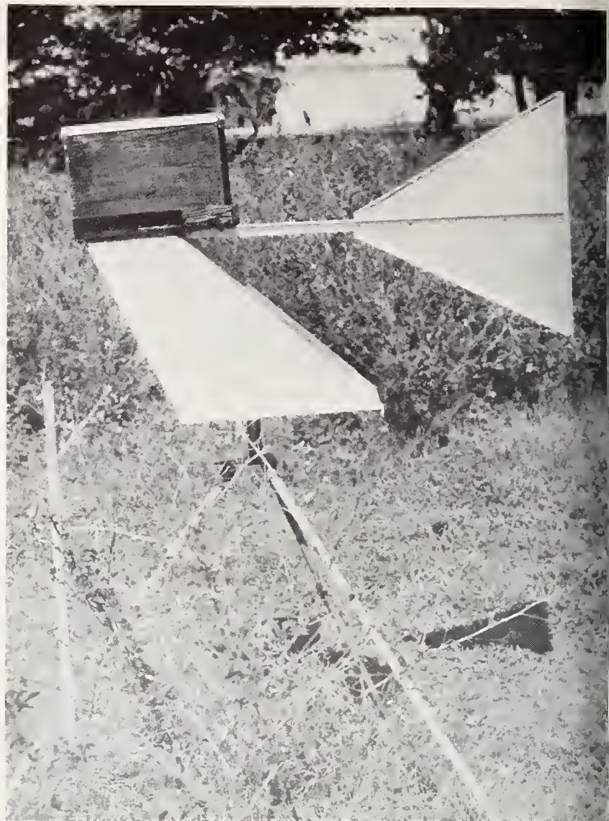

FIGURE 5.—Trap BRWV, a wind-vane trap.

ring. The base of the cone is approximately 2 inches (5 cm) above a flat plywood base that is 24 inches (61 cm) in diameter and three-fourths of an inch (1.9 cm) in thickness. A small cone, with a base diameter of 4¼ inches (10.8 cm) and a height of 5 inches (12.7 cm), has a top opening of seven-eighths of an inch (2.2 cm) that fits into the mouth of a wide-mouth, 1-gallon (3.8-liter) collection jar. Access to the pheromone attractant, which is located on the plywood base directly beneath the collection jar, is gained through a hinged door near the base of the cone.

Trap TPVB is identical to trap TP except for the addition of an inner four-vaned baffle assembly. The baffle is made of hardware cloth, one-eighth of an inch (3.2 mm) mesh, that vertically divides the inside of the cone into four equal sections. The hypothesis of this design was that the moth would be quickly induced to move upward, since it would encounter an obstruction to its movement as soon as it wandered away from the pheromone zone.

Trap TPCB is a second variation of basic trap TP. The basic dimensions are the same, but this design includes an inner cone of hardware cloth, one-eighth of an inch (3.2 mm) mesh, which extends from the plywood base into the collection jar. The screen cone dimensions, 14 inches (35.6 cm) in diameter at the base and 14 inches (35.6 cm) in height, are such that sufficient clearance is provided between the top of the screen cone and the entrance to the collection jar for free movement of the moths and easy access to the jar entrance.

Trap TP12CB is basically the same as trap TPCB, but it has smaller dimensions. The cone base diameter is 12 inches (30.5 cm), and the truncated cone height is 8 inches (20.3 cm). The base diameter of the screen cone is 6 inches (15.2 cm), and the height is also 6 inches (15.2 cm).

Figure 5 shows a side view of trap BRWV, one of the wind-vane live traps included in the evaluation trials. This trap was constructed by personnel at Agricultural Research Service's Cotton Insect Research Laboratory, Brownsville, Tex. The entrance slot for moths is visible

FIGURE 6.—Trap CSWV, a wind-vane trap.

at the lower right side of the trap. A pin bearing supports the trap on a tripod base.

Trap CSWV (fig. 6), also a wind-vane trap, was constructed by personnel at Agricultural Research Service's Cotton Pest Control Equipment and Methods Research Unit at College Station, Tex. Its basic design features are identical to those of trap BRWV, and it has approximately the same dimensions. Modifications include a sheet-metal collection container and an integral wind vane.

In preliminary operational trials, two basic traps (TP) and one wind-vane trap (CSWV) were installed in a field of pigeonpeas at the Isabela Experiment Station on the afternoon of February 11, 1977. The traps were mounted on iron-pipe posts, 1½ inches (3.8 cm) in diameter, with the trap base approximately 48 inches (1.2 m) above ground surface. The traps were placed approximately 150 feet (45.7 m) apart and were positioned so that no two traps were in line with the prevailing wind. The traps were baited with both virelure and looplure (*1*), since simultaneous use of these two pheromones was known to be feasible (*5*). The pheromones were contained in ½- by 1-inch (1.3- by 2.5-cm) laminated plastic. Each bait, virelure or looplure, contained 20 mg of active material. On the second night of operation (February 12), one trap (TP) was moved approximately one-half mile (805 m) south to a field of young tobacco and sorghum. On the third night (February 13), the three traps were operated at the original site.

All available traps were assembled and installed in a NE.–SW. line in this field on February 14 at the same mounting heights and separations used on February 11. Trap catches were very low in all traps that night, and five traps were relocated the next night to a field of older pigeonpeas about one-fourth of a mile (402 m) south of the original site. Two test sites were retained at the original location in a part of the field where the peas were vigorously fruiting.

Traps were installed at these seven sites on February 15, and a 6-day trial was initiated. The traps were serviced and moved daily, from one randomly selected location to another. Baits were renewed at the midpoint of the trial.

The results of trial 3 (table 3) were not encouraging for existing designs of nonelectric traps. Grid trap CG was the only trap that consistently caught moths. All other traps caught from none to very few moths, whereas trap CG had catches for six of seven nights of operation and caught 93% of all tobacco budworm moths and 57% of all cabbage looper moths caught.

Trial 4

Trials were resumed in the Brazos River Valley area in April 1977. A six-trap comparison trial was conducted from April 28 to May 27. Traps compared and evaluated for trapping male tobacco budworm moths included (1) standard electric-grid trap SG (fig. 1), the standard of comparison; (2) wind-vane trap CSWV (fig. 6); (3) basic trap TP (fig. 4); (4) trap TPLOC (fig. 7), a modified version of basic trap TP, with increased entrance height and an inner screen cone; (5) trap TPHC (fig. 8), a modified version of basic trap TP, with a cone constructed of galvanized wire, one-eighth of an inch (3.2 mm) mesh, instead of 28-gage galvanized sheet metal; and (6) trap TPHCP, identical to trap TPHC except for a cover of 4/1,000-inch (0.10-mm) clear plastic on the hardware-cloth cone. The traps were baited, serviced, and rotated as in trials 1 and 2.

Data obtained in trial 3 were used as a basis for three of the trap designs included in trial 4. The hardware-cloth trap was designed to elimi-

TABLE 3.—*Electric versus nonelectric trap designs for catching male tobacco budworm moths and cabbage looper moths, trial 3*[1]

Date	CG[3] Location	CG[3] Catch	TP Location	TP Catch	TPVB Location	TPVB Catch	TPCB Location	TPCB Catch	TP12CB Location	TP12CB Catch	CSWV Location	CSWV Catch	BRWV Location	BRWV Catch
TOBACCO BUDWORM MOTHS														
Feb. 14[4]	...	18	...	0	...	0	...	0	...	0	...	3	...	0
15	3	20	5	1	2	0	6	0	4	1	1	0	7	0
16	4	11	1	0	6	0	3	0	2	0	7	0	5	0
17	7	0	4	0	1	0	2	0	3	0	5	0	6	0
18	5	14	7	0	3	0	4	0	6	0	2	2	1	0
19	6	7	2	0	5	0	7	0	1	0	3	1	4	0
20	1	33	3	0	4	0	5	0	7	0	6	0	2	1
Total	...	103	...	1	...	0	...	0	...	1	...	6	...	1
Mean[5]	...	14.71a	...	0.14b	...	0b	...	0b	...	0.14b	...	0.86b	...	0.14b
CABBAGE LOOPER MOTHS														
Feb. 14[4]	...	0	...	1	...	0	...	0	...	0	...	0	...	0
15	3	11	5	2	2	0	6	0	4	0	1	0	7	1
16	4	2	1	0	6	0	3	0	2	0	7	0	5	1
17	7	4	4	0	1	0	2	0	3	2	5	0	6	0
18	5	6	7	1	3	2	4	1	6	0	2	0	1	0
19	6	8	2	1	5	0	7	0	1	0	3	1	4	2
20	1	4	3	0	4	0	5	0	7	0	6	0	2	1
Total	...	35	...	5	...	2	...	1	...	2	...	1	...	5
Mean[5]	...	5.00a	...	0.72b	...	0.29b	...	0.14b	...	0.29b	...	0.14b	...	0.71b

[1] Catches for each date used as replicate in analysis of variance.

[2] CG, modified commercial grid trap. TP, basic nonelectric trap. TPVB, trap identical to trap TP except for addition of four-vaned baffle assembly. TPCB, trap identical to trap TP except for addition of inner cone of hardware cloth. TP12CB, miniature version of trap TPCB. CSWV and BRWV, wind-vane traps.

[3] 33 specimens of male *Leucania incognita* Barnes and McDonnough were also trapped during this period; 73% of these were trapped by trap CG.

[4] Location numbers not applicable for Feb. 14 because of change of test site.

[5] Means not having a letter in common are significantly different at the 1% level by Duncan's multiple-range test.

FIGURE 7.—Trap TPLOC, a modified version of basic trap TP. Note increased entrance space and inner screen cone.

FIGURE 8.—Trap TPHC, a hardware-cloth trap.

nate any obstructions to dispersion of the pheromone that might exist in the basic sheet-metal design of trap TP. The clear plastic cover on trap TPHCP was used to create a lighting environment similar to that of trap TPHC, so that obstructive effects could be identified. Study of the effect of a wider access opening (and easier diffusion of pheromone) was of interest in the design of trap TPLOC. Trap CSWV and trap TP were included because of the limited evaluation obtained in trial 3.

Results of these comparisons are presented in table 4. Trap SG significantly outperformed all other traps, but the hardware-cloth traps, TPHC and TPHCP, caught 35% and 25% of the total number of moths caught by trap SG. Trap TP caught no moths during the entire trial, and trap TPLOC caught only one moth. The fact that trap TPHCP, with the plastic-covered hardware cloth, was relatively effective compared to traps TP and TPLOC suggests that light blockage was responsible for a large portion of the poor performance of basic trap TP

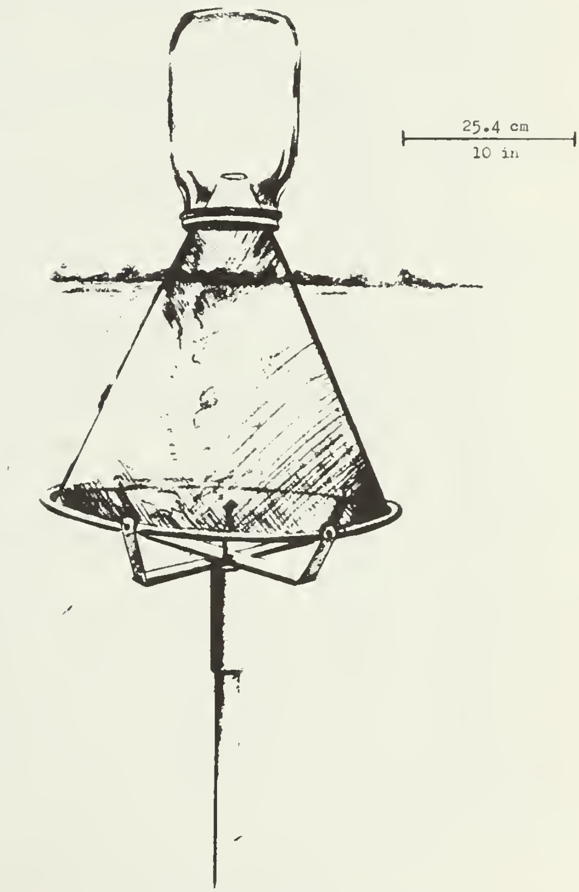

FIGURE 9.—Trap 3HB, the best nonelectric trap. Trap is identical to trap TPHC but without plywood bottom.

TABLE 4.—*Electric versus nonelectric trap designs for catching male tobacco budworm moths, trial 4*

Date	Trap[1]												Replicate[2]
	SG		CSWV		TP		TPLOC		TPHC		TPHCP		
	Location	Catch	Location	Catch	Location	Catch	Location	Catch	Location	Catch	Location	Catch	
April 28	2	1	1	0	3	0	4	0	5	0	6	0	1
29	3	0	6	0	1	0	5	0	2	1	4	0	1
30	1	0	3	0	5	0	6	0	4	0	2	0	1
May 1	5	0	2	1	4	0	1	0	6	1	3	0	1
2	6	0	4	0	2	0	3	0	1	0	5	2	1
3	4	0	5	0	6	0	2	0	3	0	1	0	1
4	3	6	6	0	4	0	2	0	5	0	1	0	2
5	6	5	4	0	1	0	5	0	3	1	2	0	2
6	4	3	5	1	2	0	6	0	1	0	3	0	2
7	5	0	1	0	3	0	4	0	2	0	6	0	2
8	1	1	2	0	5	0	3	0	6	3	4	0	2
9	2	2	3	0	6	0	1	0	4	3	5	2	2
10	2	4	6	1	3	0	4	1	5	1	1	1	3
11	5	0	4	0	1	0	6	0	3	0	2	1	3
12	6	0	5	0	2	0	3	0	1	0	4	0	3
13	4	2	1	0	6	0	5	0	2	1	3	0	3
14	1	1	3	2	5	0	2	0	4	1	6	0	3
15	3	1	2	1	4	0	1	0	6	0	5	3	3
16	2	4	1	0	3	0	4	0	5	1	6	1	4
17	3	0	6	0	1	0	5	0	2	0	4	0	4
18	1	1	3	2	5	0	6	0	4	1	2	0	4
19	5	3	2	0	4	0	1	0	6	0	3	1	4
20	6	3	4	1	2	0	3	0	1	4	5	0	4
21	4	4	5	0	6	0	2	0	3	1	1	0	4
22	3	1	6	0	4	0	2	0	5	0	1	0	5
23	6	5	4	0	1	0	5	0	3	0	2	0	5
24	4	3	5	0	2	0	6	0	1	0	3	1	5
25	5	7	1	1	3	0	4	0	2	1	6	0	5
26	1	0	2	0	5	0	3	0	6	1	4	3	5
27	2	1	3	0	6	0	1	0	4	2	5	0	5
Total	...	58	...	10	...	0	...	1	...	23	...	15	...
Mean[3]	...	1.93a	...	0.33bc	...	0.0c	...	.03c	...	0.77b	...	0.50bc	...

[1] SG, standard grid trap. CSWV, wind-vane trap. TP, basic nonelectric trap. TPLOC, modified version of trap TP, with increased entrance height and an inner screen cone. TPHC, hardware-cloth trap. TPHCP, trap identical to trap TPHC except for plastic cover on hardware-cloth cone.

[2] Numbers show groupings by which data were analyzed, i.e., all 1's were of the same replicate, all 2's were of the same replicate, etc.

[3] Means not having a letter in common are significantly different at the 5% level by Duncan's multiple-range test.

and its modified versions constructed of opaque materials.

Trial 5

The second trial in 1977 in the Brazos River Valley area was conducted from May 28 to June 27 to evaluate six traps for trapping male tobacco budworm moths. The traps included were (1) standard grid trap SG (fig. 1), the standard of comparison; (2) wind-vane trap CSWV (fig. 6); (3) hardware-cloth trap TPHC (fig. 8); (4) hardware-cloth trap TPHCP; (5) hardware-cloth trap TPHCV, identical to trap TPHC but with a small ½- by 1-inch (1.3- by 2.5-mm) piece of resin strip, containing dichlorvos insecticide, in the collection jar; and (6) trap 3HB (fig. 9), identical to trap TPHC but without the plywood bottom. The traps were baited and serviced as described for trials 1, 2, and 4.

Results of trial 5 (table 5) indicate that the dichlorvos killing agent may have seriously inhibited the performance of trap TPHCV. It is not known whether trap performance was impaired by repulsion of moths at the entrance to the collection jar or before they had entered the trap. Trap 3HB caught 52% of the total number of moths caught by standard trap SG, and its performance was significantly better than those of the other nonelectric traps.

DISCUSSION

The results of trials 1 and 2 led us to conclude that substantial reductions in grid dimensions were not possible without severe loss of trap performance, so our efforts in trial 3 were directed toward development of nonelectric trap designs. Basic objectives were to design a simple and inexpensive nonelectric trap with performance equal to at least 33% of that of our large grid traps, SG and CG. As indicated previously, initial design efforts resulting in the trap configuration designated as TP took concepts from both a saucer trap and a wind-vane trap, both of which were known to have successfully trapped tobacco budworm moths. The TP design eliminated the need for sticky material (saucer trap) and provided substantial size reduction by eliminating the need for variable orientation according to wind direction (wind-vane trap).

Although data from trial 3 provided little evidence for explaining the poor performance of the nonelectric traps, certain hypothetical explanations were considered. First, all nonelectric traps depend upon induced behavior to effect capture. The moth must detect the pheromone stream or cloud, follow it to the trap, enter a slotted opening, and then move to the top of the trap. Second, movement within the trap is thought to be induced by inherent escape reactions after the moth discovers it is within a confined area. Third, movement to the top of the trap is thought to be guided by light (starlight and moonlight) visible through the collection jar, or screened collection box, at the top of the trap.

Thus, certain conditions must exist and specific behavioral actions must occur in the proper sequence to effect capture of this particular moth species. Lack of wind movement, for example, would eliminate the plume of pheromone which the moth follows into the trap. Conversely, high winds (over 6 mi/h) would not only cause excessive diffusion of the pheromone plume but would prevent directed moth flight. Heavy cloud cover would drastically reduce or eliminate incident skylight or moonlight at the top of the trap, preventing orientation of the moth toward the escape (capture) path.

Precise and detailed measurement of critical environmental variables was not attempted during trial 3 because of equipment logistics problems. However, we suspect that the two aforementioned factors, wind and skylight, could have had significant influences on captures in the nonelectric traps. The nights were observed to be extremely calm after 11:00 p.m. Winds were usually strong late in the afternoons, and it was quite calm during the normal period of maximum response for the tobacco budworms, 0200–0300 (unpublished data). Thus, we can hypothesize that there was not enough air movement to create a guidance plume from the nonelectric traps because of structural trapping and obstruction to the pheromone. In contrast, the grid wires surrounding the pheromone in the electric traps provided little or no obstruction to pheromone movement; thus, the slightest breeze was likely to produce a plume of pheromone suitable for orienting a responsive moth.

We can also hypothesize that lack of moonlight was a negative influence, since recent re-

TABLE 5.—*Electric versus nonelectric trap designs for catching male tobacco budworm moths, trial 5*

Date	SG Location	SG Catch	CSWV Location	CSWV Catch	3HB Location	3HB Catch	TPHCV Location	TPHCV Catch	TPHC Location	TPHC Catch	TPHCP Location	TPHCP Catch	Replicate[2]
May 28	2	0	6	0	3	0	4	0	5	0	1	0	1
29	5	1	4	0	1	0	6	0	3	0	2	0	1
30	6	2	5	2	2	0	3	0	1	0	4	0	1
31	4	1	1	0	6	0	5	0	2	1	3	0	1
June 1	1	1	3	0	5	0	2	0	4	0	6	1	1
2	3	0	2	0	4	0	1	0	6	1	5	1	1
3	2	1	1	0	3	0	4	0	5	0	6	0	2
4	3	1	6	0	1	0	5	0	2	0	4	0	2
5	1	1	3	1	5	2	6	0	4	0	2	1	2
6	5	2	2	0	4	1	1	0	6	3	3	0	2
7	6	5	4	1	2	4	3	0	1	0	5	0	2
8	4	0	5	0	6	0	2	0	3	1	1	0	2
9	3	2	6	0	4	1	2	0	5	0	1	0	3
10	6	5	4	0	1	0	5	0	3	0	2	1	3
11	4	5	5	2	2	0	6	0	1	0	3	0	3
12	5	12	1	0	3	8	4	0	2	0	6	2	3
13	1	3	2	0	5	6	3	0	6	4	4	0	3
14	2	11	3	0	6	14	1	0	4	4	5	4	3
16	2	6	6	0	3	4	4	0	5	0	1	0	4
17	5	6	4	1	1	0	6	2	3	2	2	0	4
18	6	10	5	0	2	0	3	0	1	0	4	0	4
19	4	2	1	0	6	1	5	0	2	0	3	0	4
20	1	0	3	0	5	1	2	1	4	0	6	2	4
21	3	3	2	0	4	0	1	0	6	0	5	0	4
22	2	1	1	0	3	1	4	0	5	1	6	0	5
23	3	1	6	0	1	0	5	0	2	0	4	0	5
24	1	2	3	0	5	1	6	0	4	0	2	0	5
25	5	1	2	0	4	0	1	0	6	0	3	0	5
26	6	0	4	0	2	0	3	0	1	0	5	0	5
27	4	0	5	0	6	0	2	0	3	0	1	0	5
Total	...	85	...	7	...	44	...	3	...	17	...	12	...
Mean[3]	...	2.83a	...	0.23c	...	1.47b	...	0.10c	...	0.57c	...	0.40c	...

Trap[1]: SG, CSWV, 3HB, TPHCV, TPHC, TPHCP.

[1] SG, standard grid trap. CSWV, wind-vane trap. 3HB, trap identical to trap TPHC but without plywood bottom. TPHCV, trap identical to trap TPHC but with killing agent in collection jar. TPHC, hardware-cloth trap. TPHCP, trap identical to trap TPHC except for plastic cover on hardware-cloth cone.

[2] Numbers show groupings by which data were analyzed, i.e., all 1's were of the same replicate, all 2's were of the same replicate, etc.

[3] Means not having a letter in common are significantly different at the 5% level by Duncan's multiple-range test.

search with virelure-baited grid traps (*2*) indicates that pheromone trap catches increase with increasing intensities of moonlight. This phenomenon is thought to be associated with moonlight-induced suppression of activity and pheromone release by the native females and a resultant decrease in competition for the traps with a synthetic pheromone. Dark of the moon occurred February 17, the midpoint of the trapping trials. In addition, the lack of moonlight could have severely limited the performances of the nonelectric traps because of the need for light to orient and guide the moths to the top of the trap.

Trial 5 included the four best traps from trial 4 and introduced two new variables: (1) the effect of using a killing agent within the collection jar (trap TPHCV) and (2) the effect of removing the plywood base from below the hardware-cloth trap (trap 3HB). The performance of trap 3HB was quite encouraging in that it exceeded our previously established performance goals. This trap appears to be a practical and inexpensive design which opens up possibilities for widespread use of nonelectric traps for monitoring tobacco budworm moth populations. Further work is underway to (1) determine optimum trap size, (2) determine the best position for mounting pheromone attractant within the trap, (3) develop a replacement for the glass-jar collecting device, and (4) develop mathematical models initiated by pheromone-trap catch data that will accurately predict the timing and magnitude of future tobacco budworm populations.

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